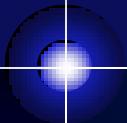
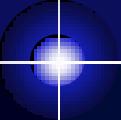


The Role of Representing Cloud Processes in the Simulation of Climate



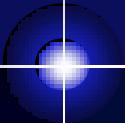
Cristiana Stan

Center for Ocean-Land-Atmosphere Studies, Calverton MD 20705



Outline

- Background Motivation
- Models Description
- Simulation of the Mean Climate
- Simulation of Tropical Variability on Intraseasonal-to-interannual Time-scales
- Conclusions



Common biases in current generation of CGCMs

- **Errors in the precipitation distribution with**
 - Second spurious Inter-Tropical Convergence Zone (ITCZ) south of the equator in the eastern Pacific
 - Deficit or excessive precipitation distribution over the Indo-Pacific Warm Pool
- **ENSO with**
 - Unrealistic amplitude
 - Period that is too long or too short
 - Regular occurrence
- **Weak ENSO-monsoon teleconnection**
- **Misrepresentation of the MJO**
 - Underestimation of the strength and coherence of convection and wind variability
 - Life cycle

Where to Go?

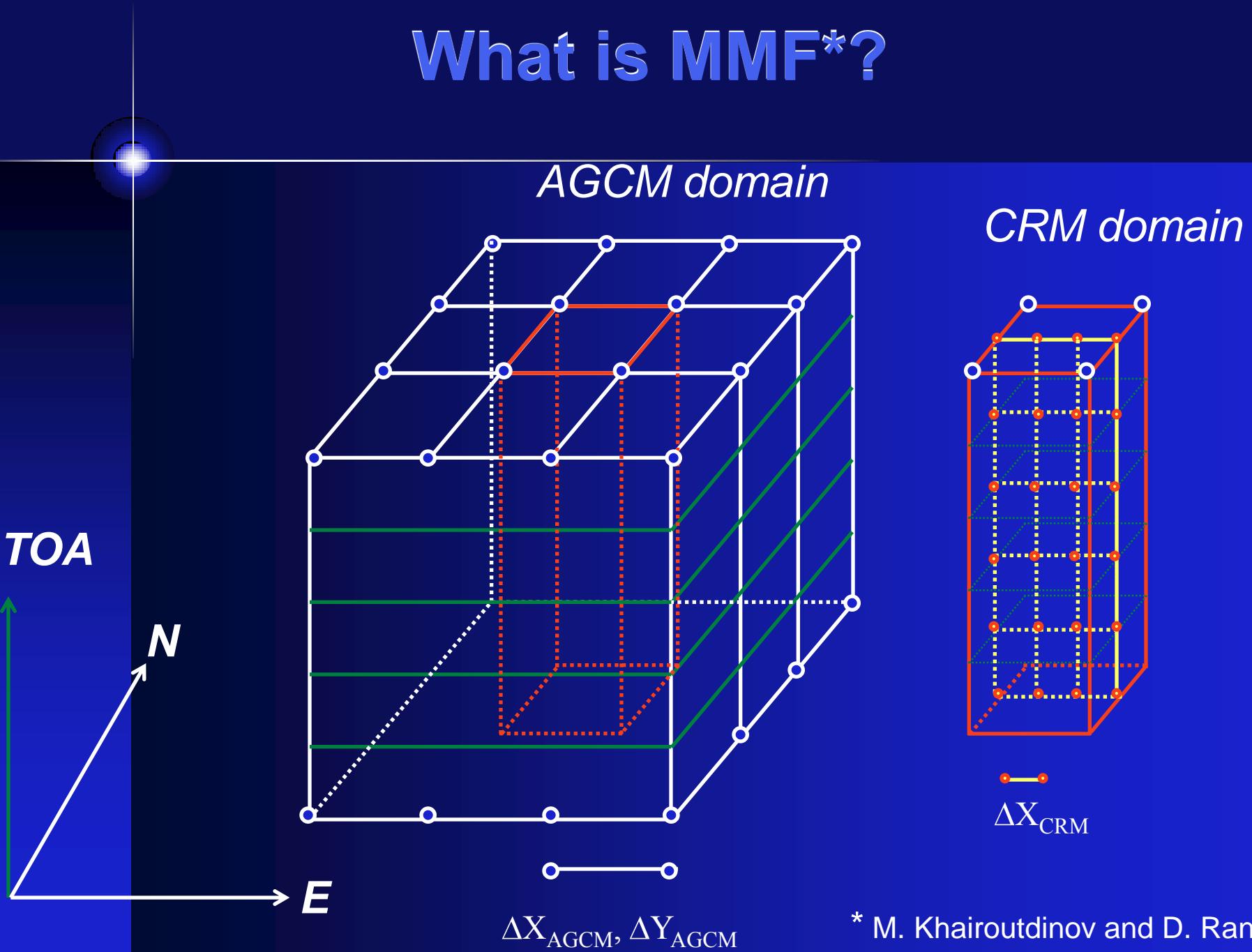
Increase
horizontal
resolution?



Toward
cloud processes
resolving?
MMF?

“Thinker of Hamangia”
Romanian Neolithic Artifact

What is MMF*?



Models Configuration

	<i>SP-CCSM</i>	<i>Ctl-CCSM</i>	<i>HR-CCSM</i> <i>(PetaApps Proj)</i>
Horiz. Res.	T42 (sld ¹)	T42 (sld ¹)	0.47x0.63 (fv ²)
Vert. levels	30	26	26
Deep conv.	CRM ³	ZM	ZM_New ⁴
Shallow conv.	CRM ³	Hack	Hack
Horiz. Res.	gx3v5	gx3v5	tx0.1v2
Vert. levels	25	25	40
Ice model	CSIM4	CSIM4	CICE4.0
Land model	CLM3.0	CLM3.0	CLM3.5

¹ semi-Lagrangian dynamical core

² finite-volume dynamical core

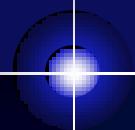
³ M. Khairoutdinov and D. Randall

⁴ Neale et al., 2008

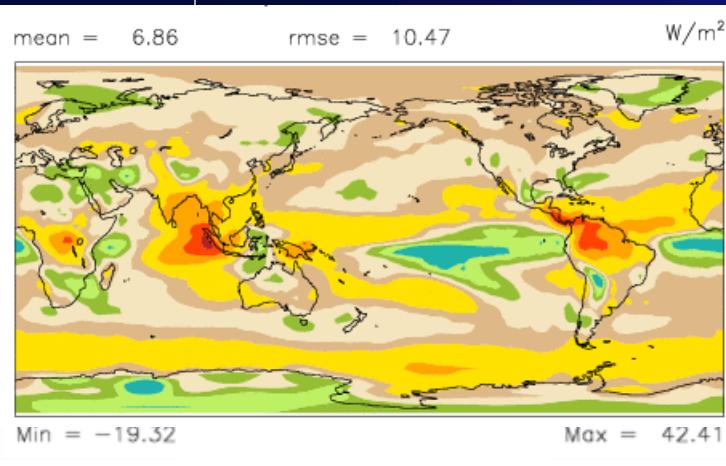
TOA Radiation

Annual Mean Climatology

(models: 0004–0023; ERBE: 1985–1989)



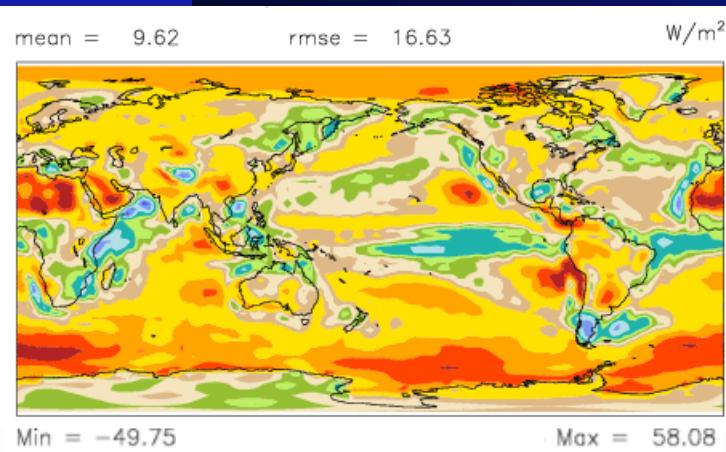
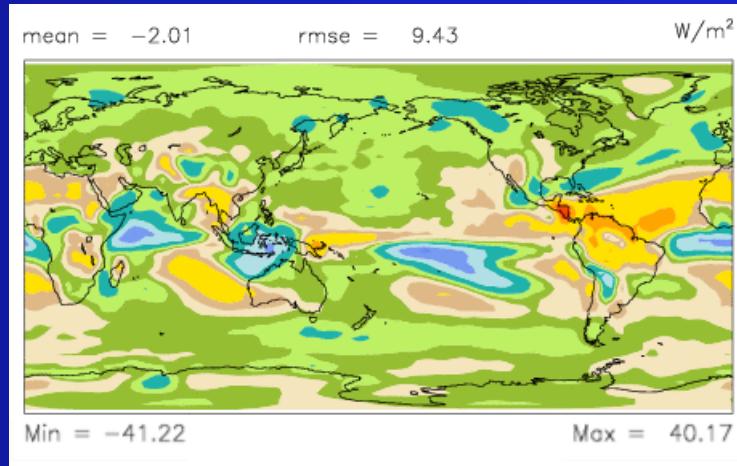
SP-CCSM–ERBE
(R_{net} error = +2.76)



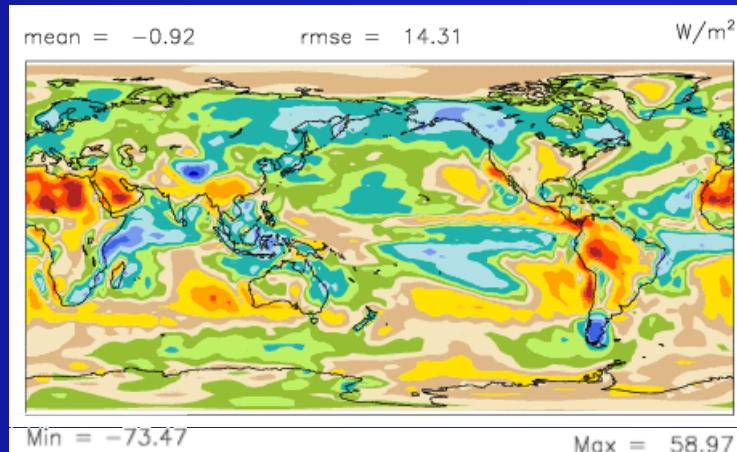
Upward LW



Ctl-CCSM–ERBE
(R_{net} error = +1.09)



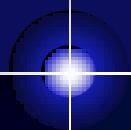
Net SW



TOA Radiation

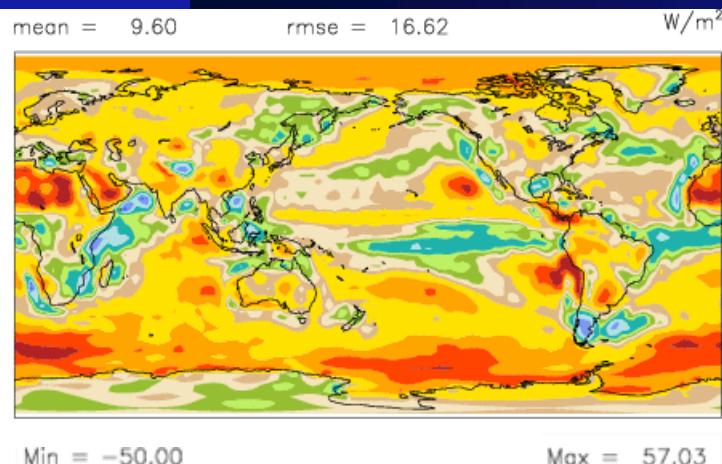
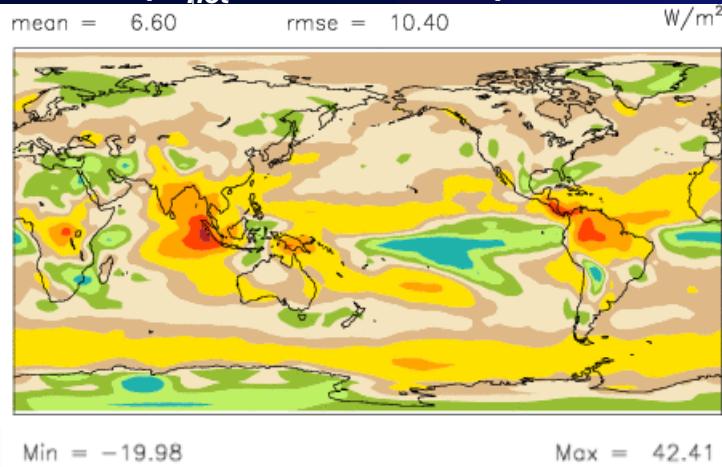
Annual Mean Climatology

(models: 0016–0020; ERBE: 1985–1989)



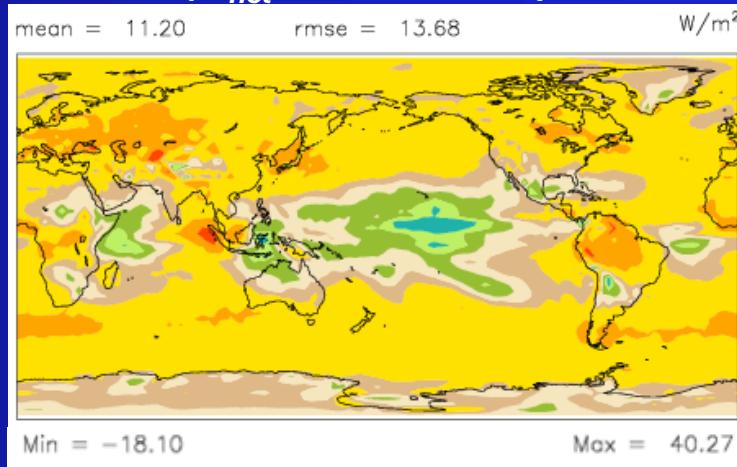
SP-CCSM–ERBE

(R_{net} error = +2.76)



HR-CCSM–ERBE

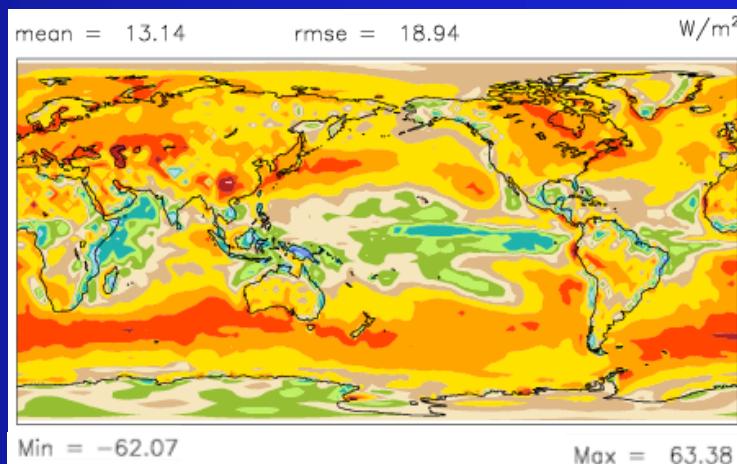
(R_{net} error = +1.94)



Upward LW



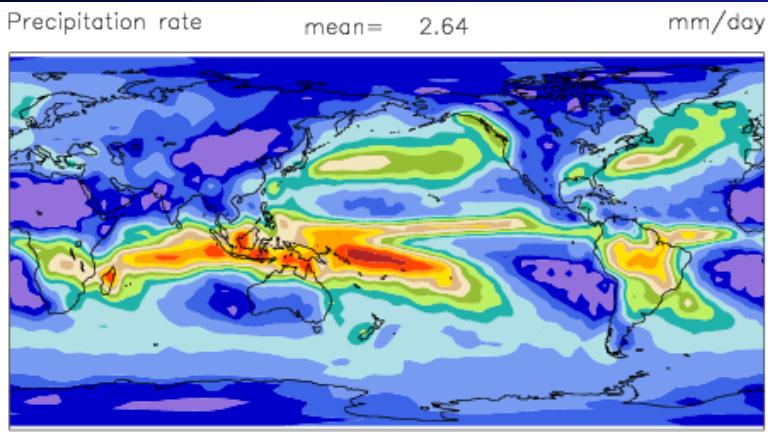
Net SW



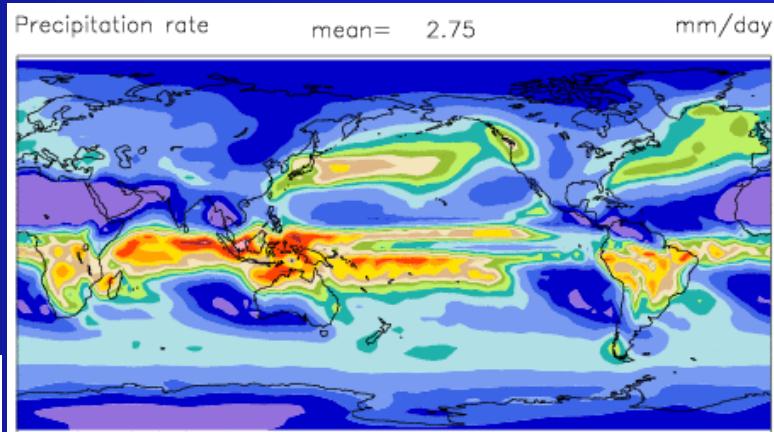
Precipitation Simulation

Boreal Winter Climatology

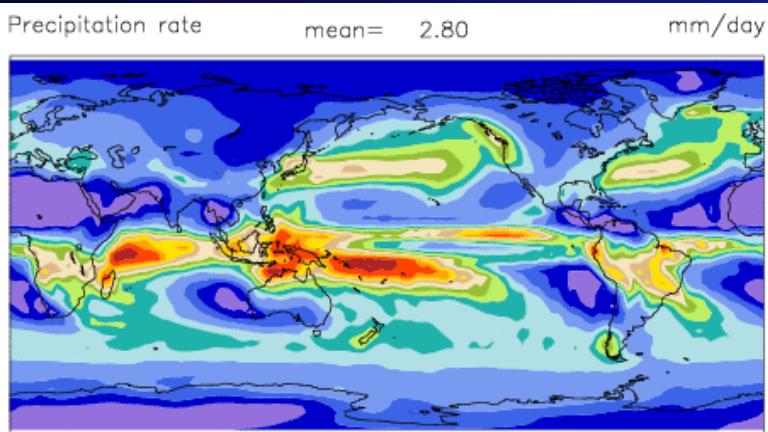
CMAP: 1979–1998



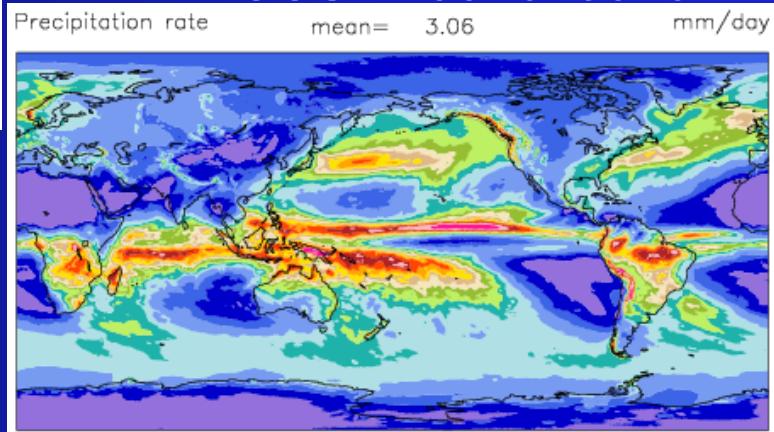
Ctl-CCSM: 0004–0023



SP-CCSM: 0004–0023



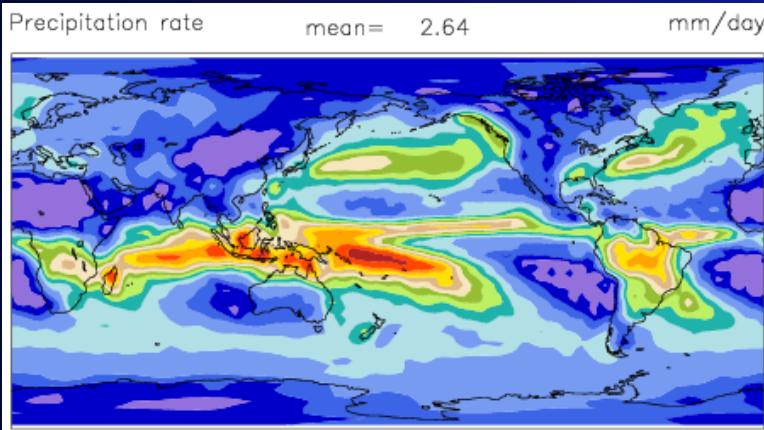
HR-CCSM: 0016–0020



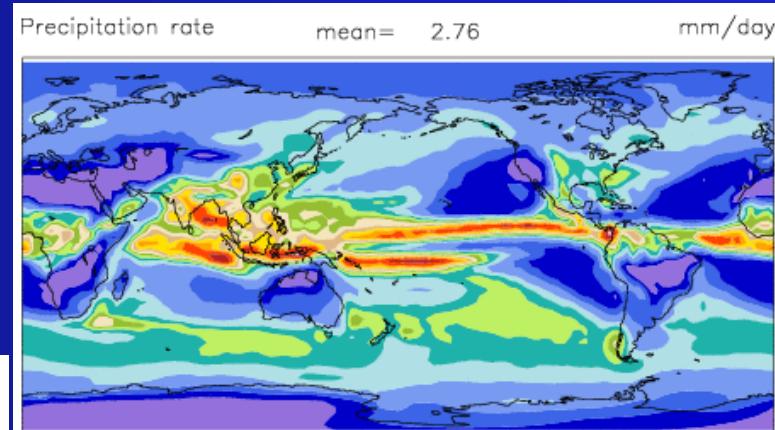
Precipitation Simulation

Boreal Summer Climatology

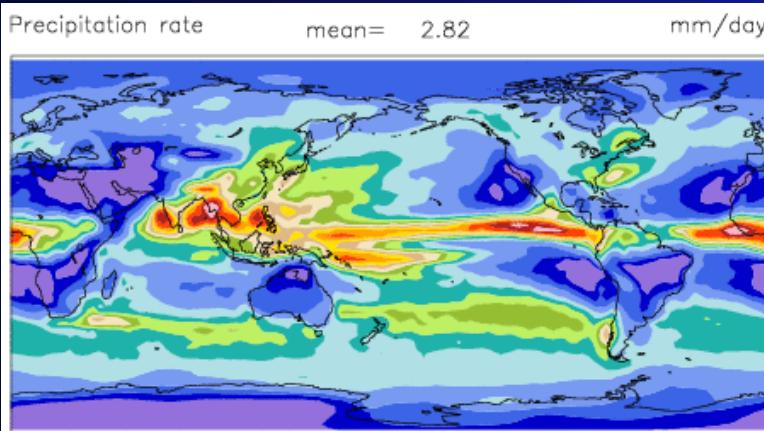
CMAP: 1979–1998



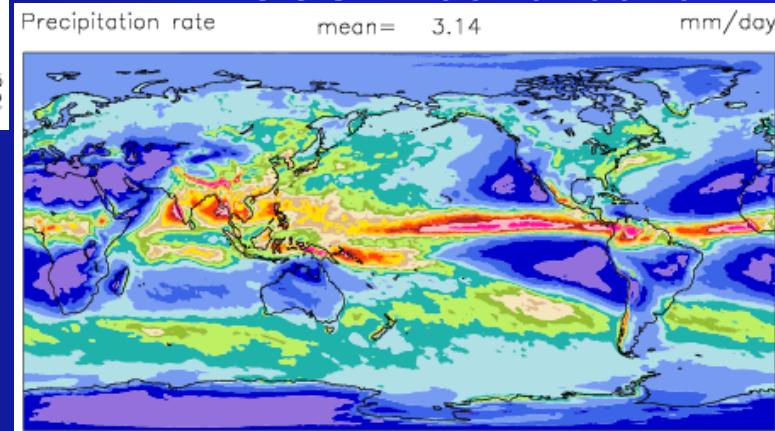
Ctl-CCSM: 0004–0023



SP-CCSM: 0004–0023



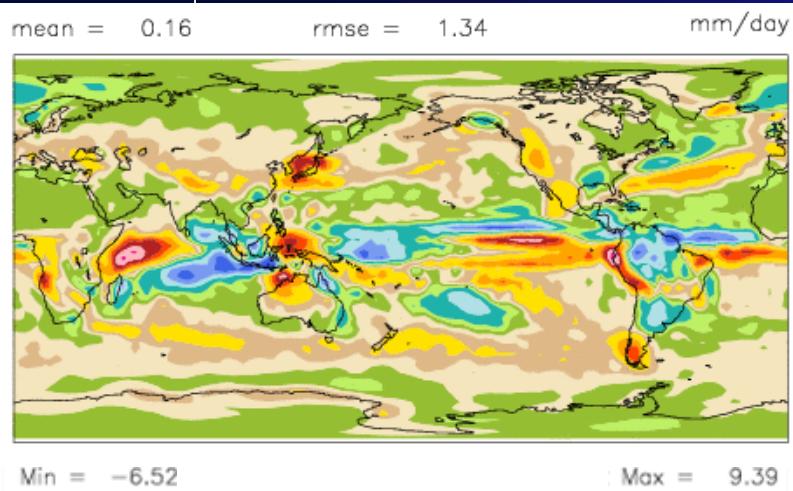
HR-CCSM: 0016–0020



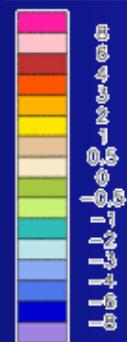
Precipitation Bias

(models: 004–0023; CMAP:1979–1998)

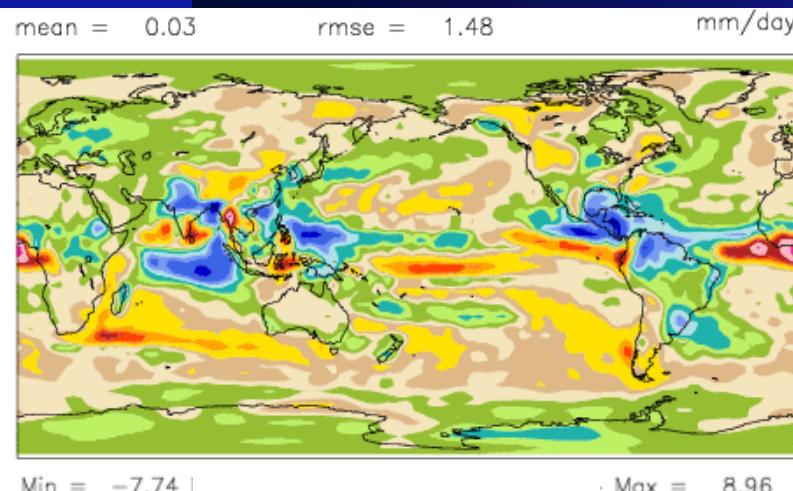
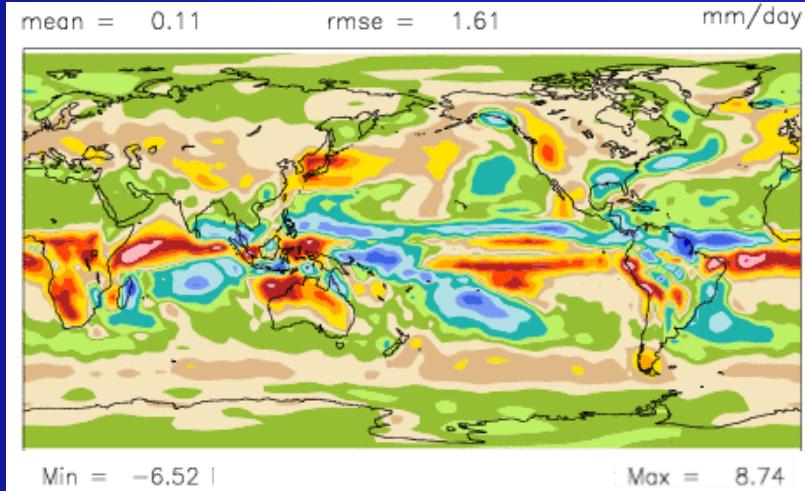
SP-CCSM–CMAP



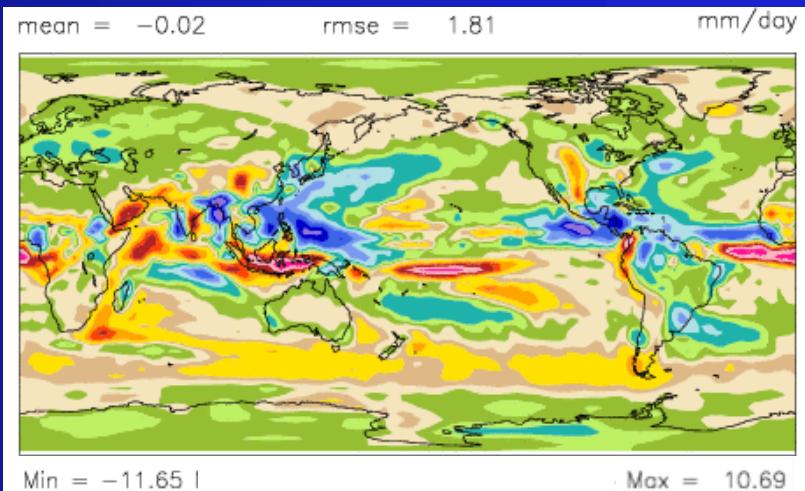
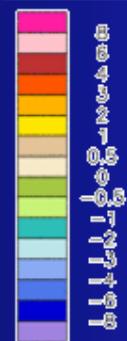
DJF



CtI-CCSM–CMAP



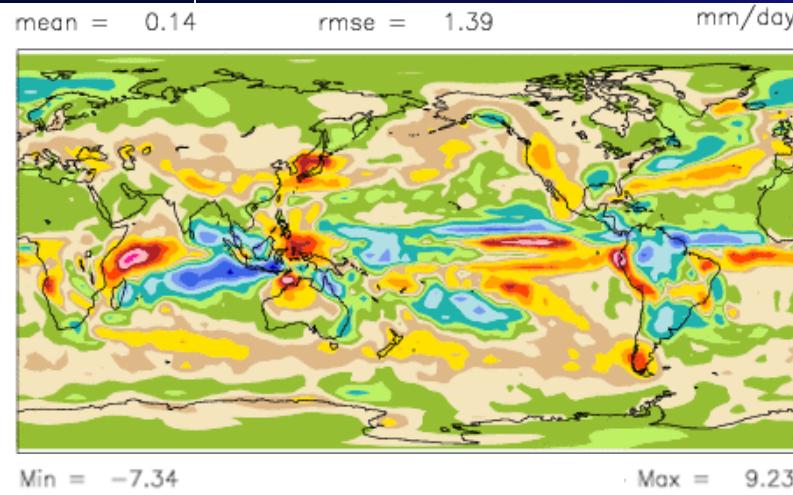
JJA



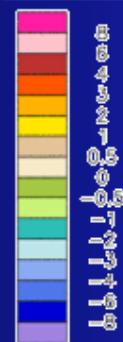
Precipitation Bias

(models:0016–0020; CMAP:1979–1998)

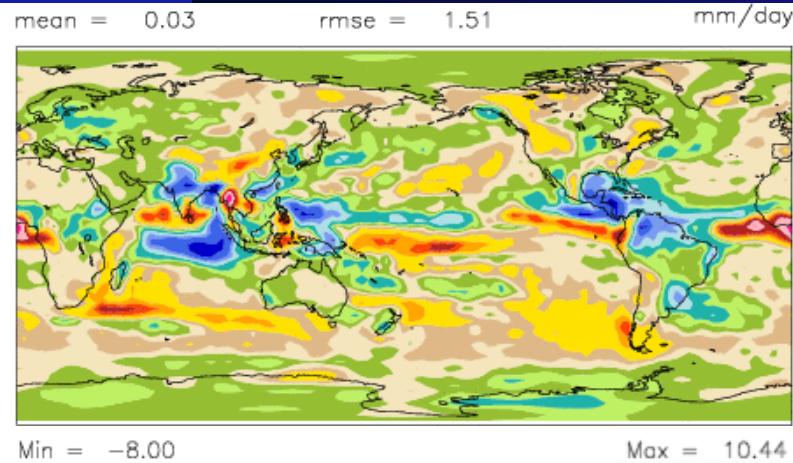
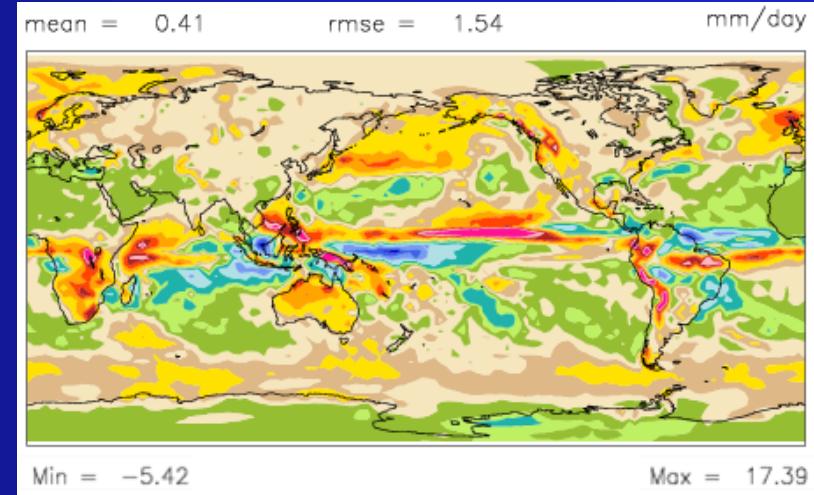
SP-CCSM–CMAP



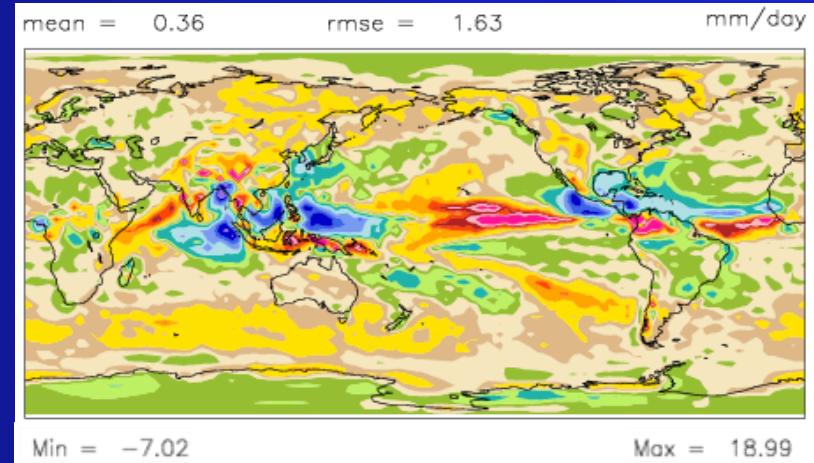
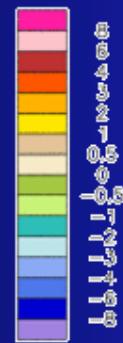
DJF



HR-CCSM–CMAP



JJA



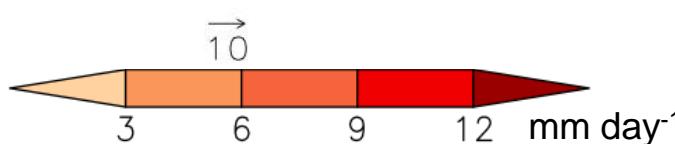
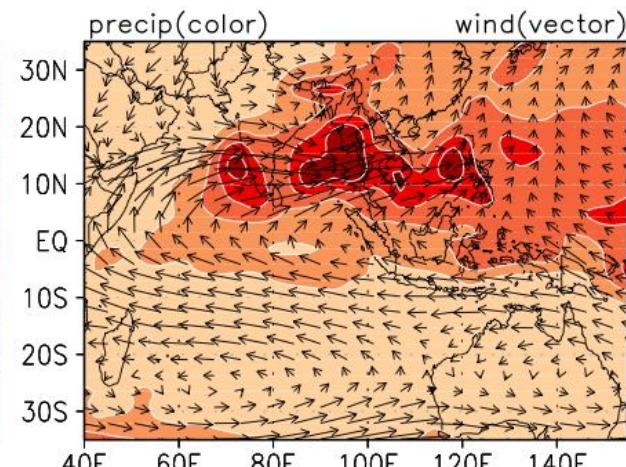
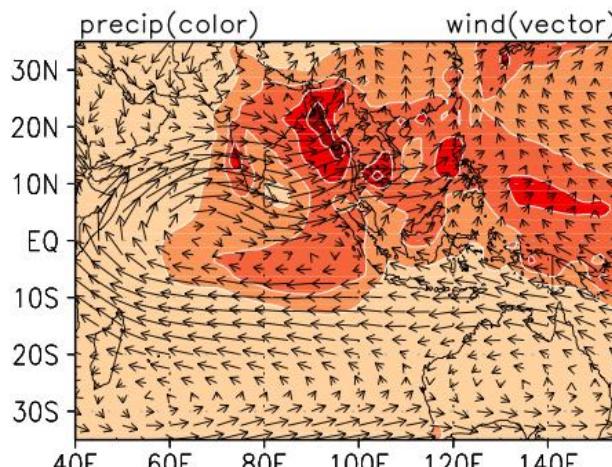
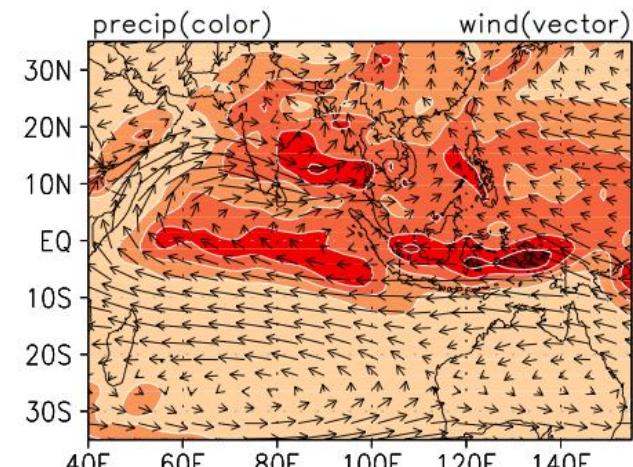
Indian Monsoon

JJAS Climatology (Precipitation, 850-hPa Wind)

Ctl-CCSM
(0004–0023)

GPCP/NCEP Rean
(1979–2003)

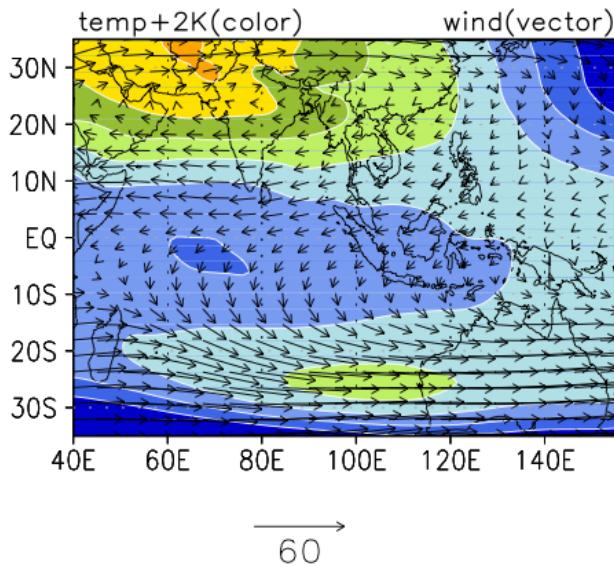
SP-CCSM
(0004–0023)



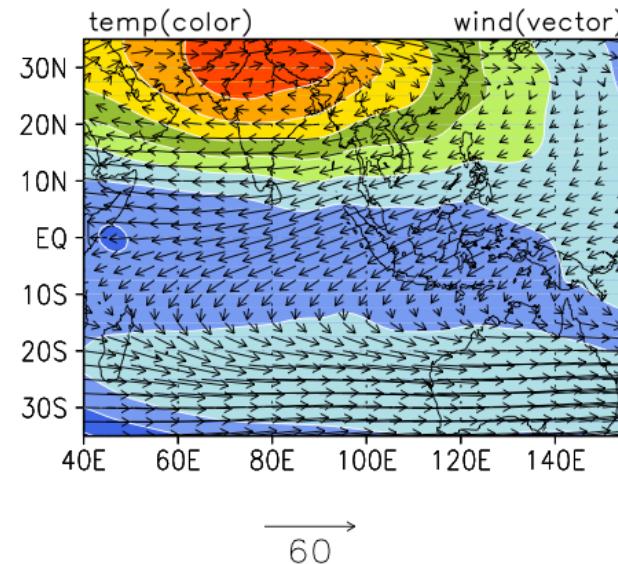
Indian Monsoon

JJAS Climatology (200-hPa Temperature, Wind)

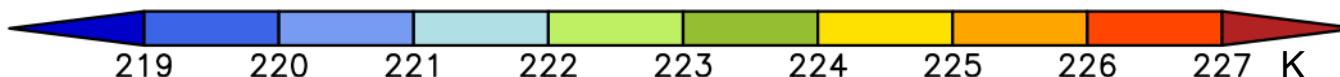
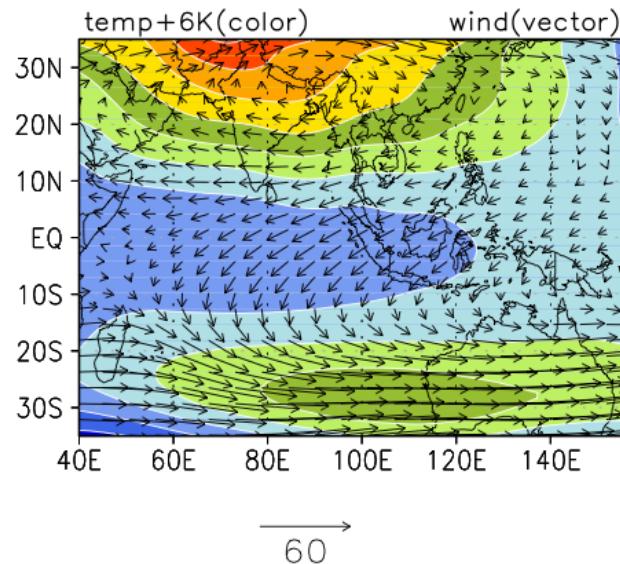
Ctl-CCSM
(0004–0023)



NCEP Rean
(1979–2003)



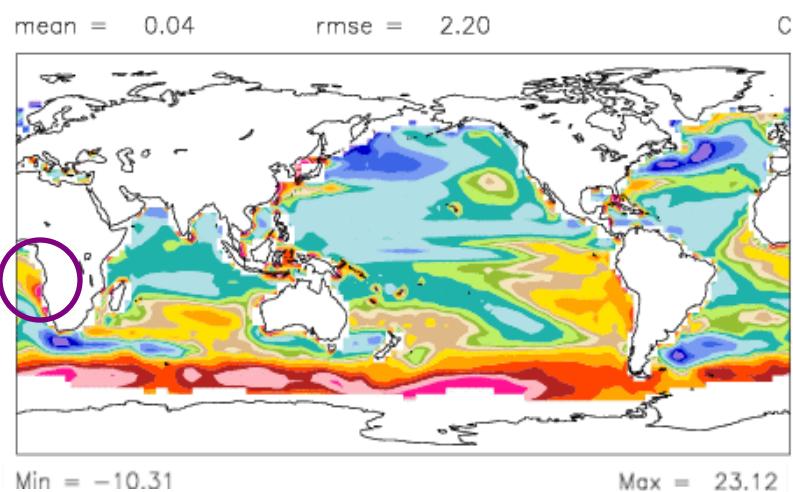
SP-CCSM
(0004–0023)



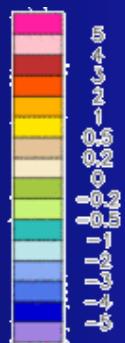
SST Bias

(models:0004–0023; HadISST:1982–2001)

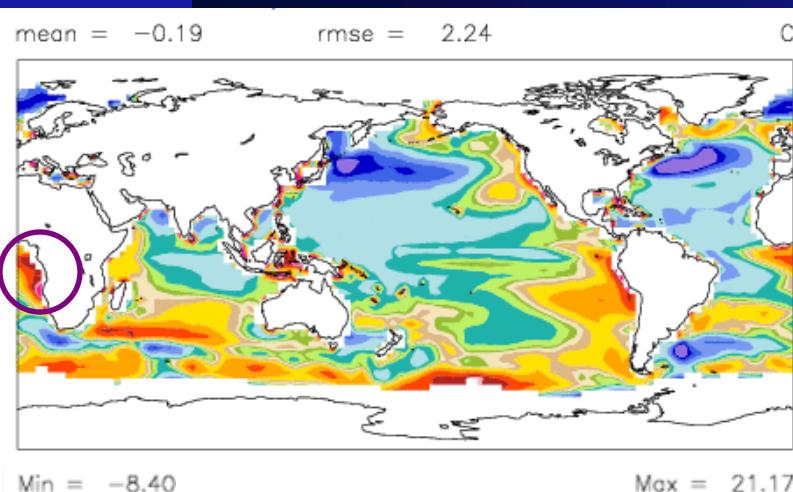
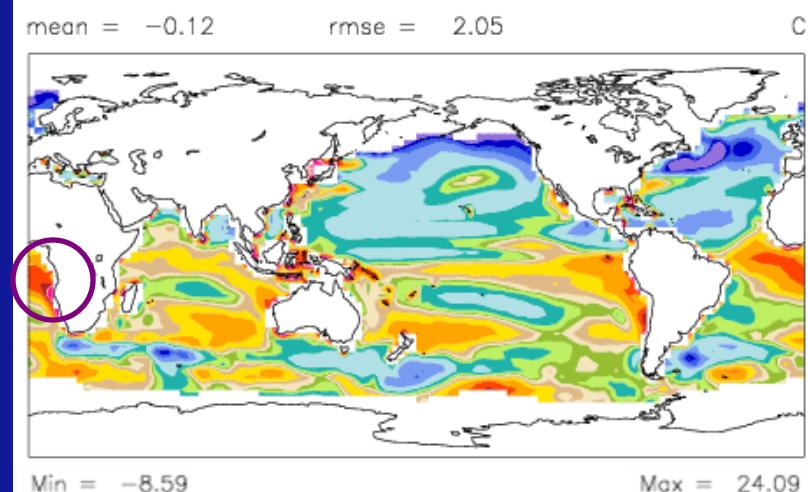
SP-CCSM–HadISST



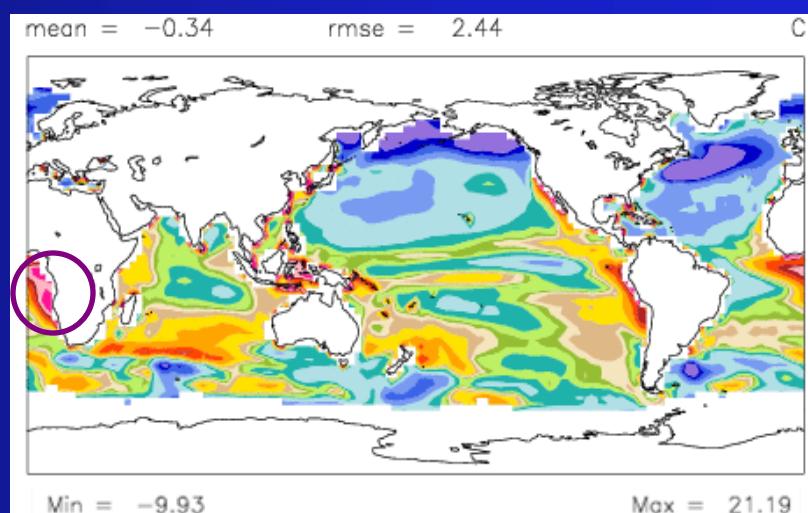
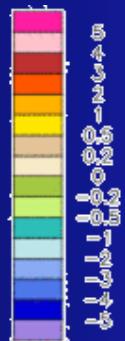
DJF



Ctl-CCSM–HadISST



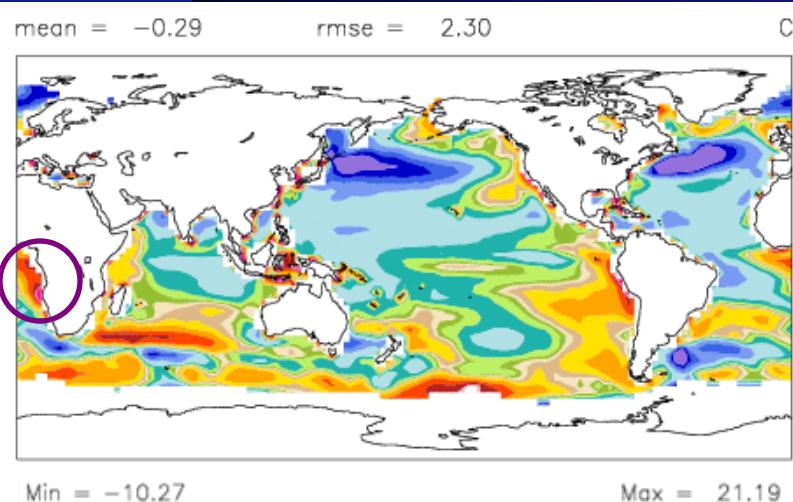
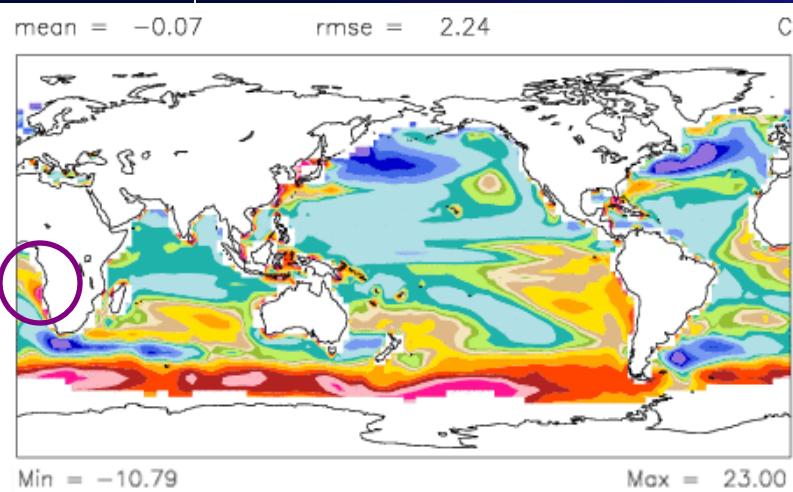
JJA



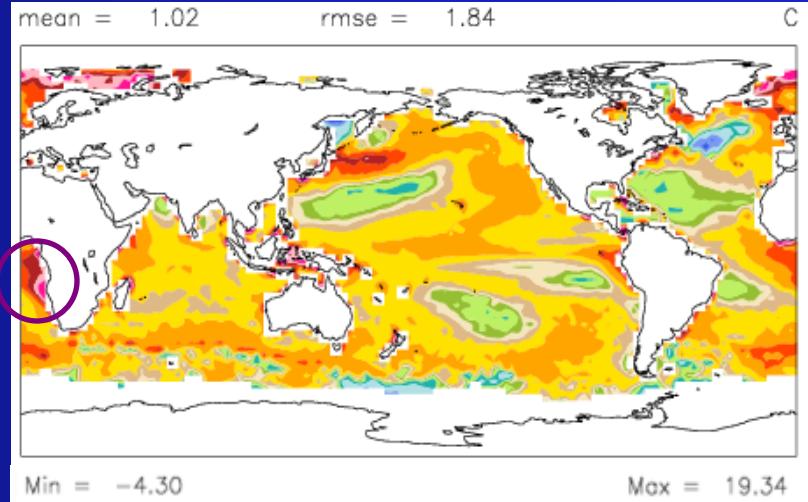
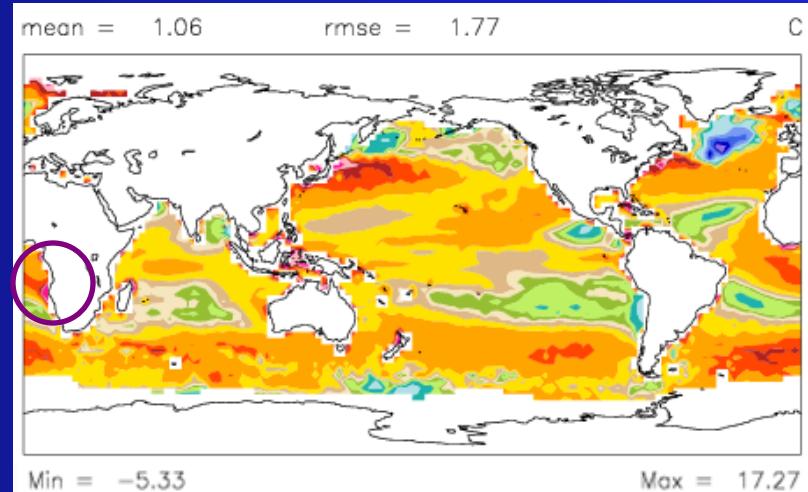
SST Bias

(models: 0016–0020; HadISST:1982–2001)

SP-CCSM–HadISST

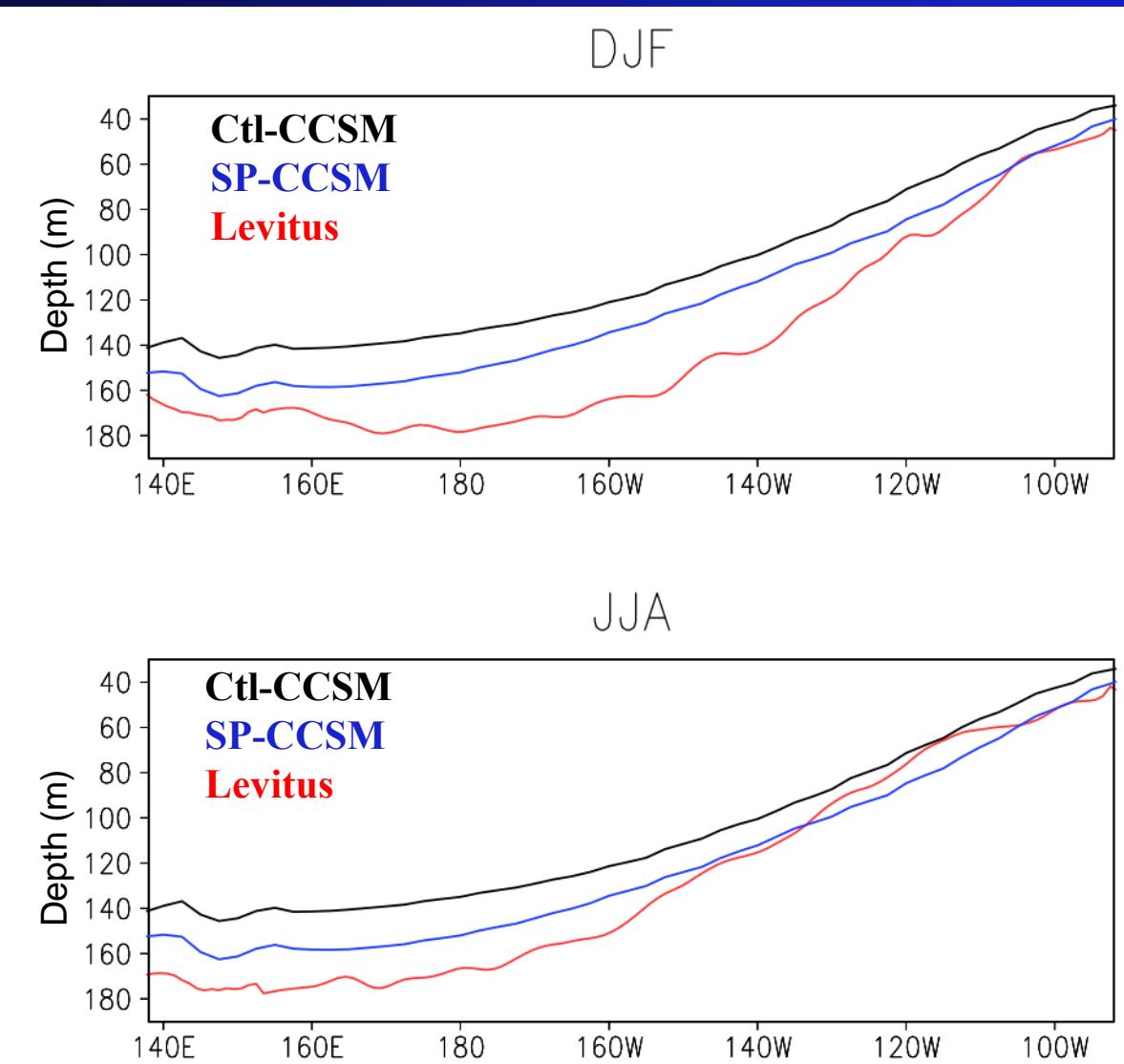


HR-CCSM–HadISST



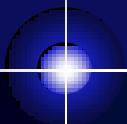
20-degree Isotherm, 5S-5N

(models: 0004–0023, Levitus: WAO 1998)

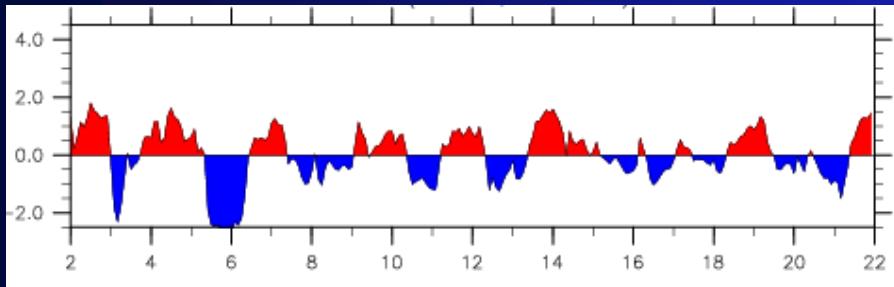


ENSO Simulation

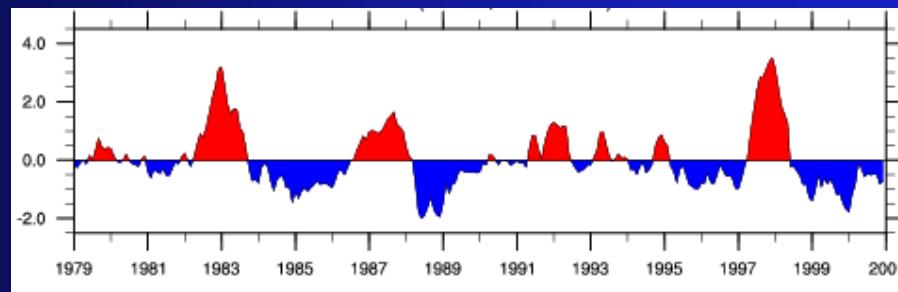
Nino 3 (5S–5N,150W–90W)



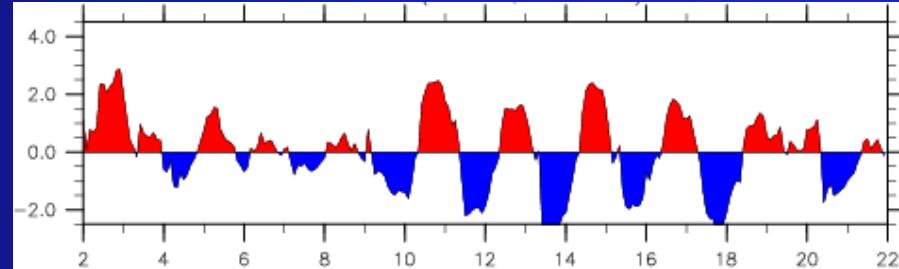
SP-CCSM
(0002–0023)



NCEP Rean.
(1979–2001)

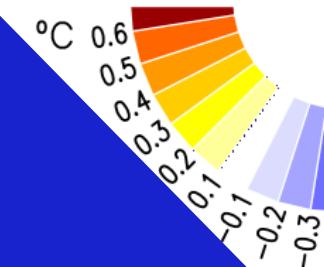
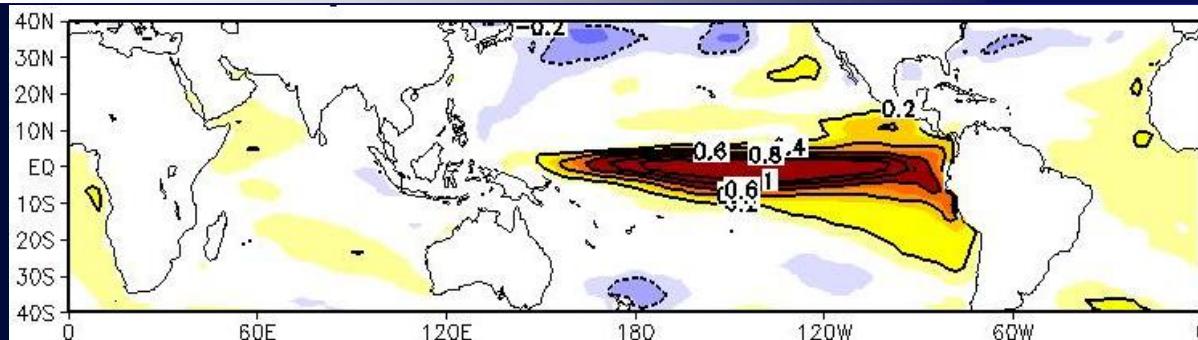


Ctl-CCSM
(0002–0023)

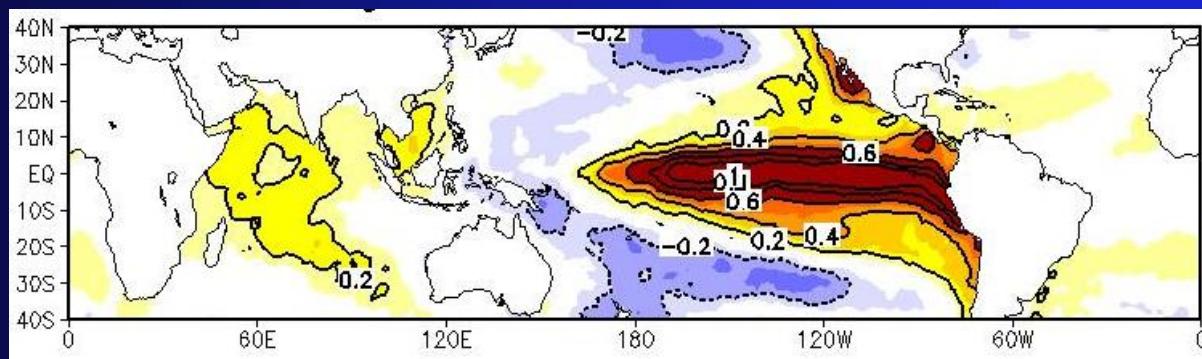


SSTA Regression with Niño3.4

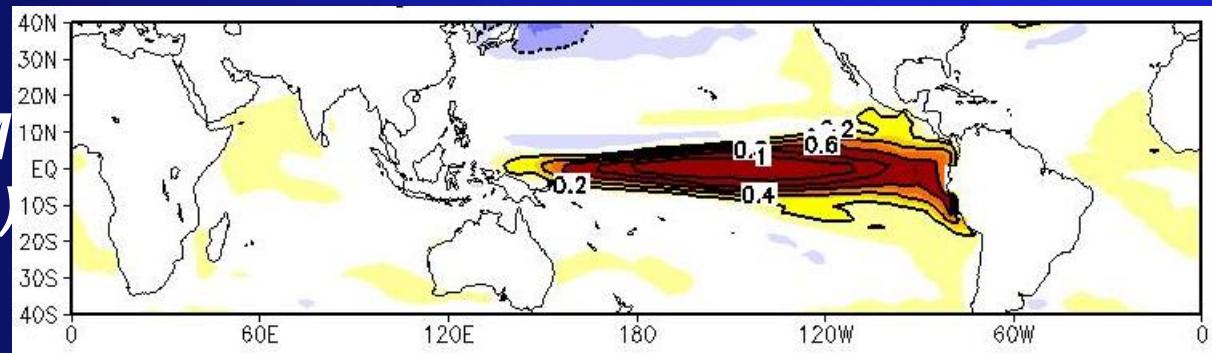
SP-CCSM
(0002–0023)



HadISST
(1948–1998)



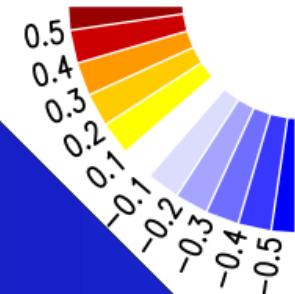
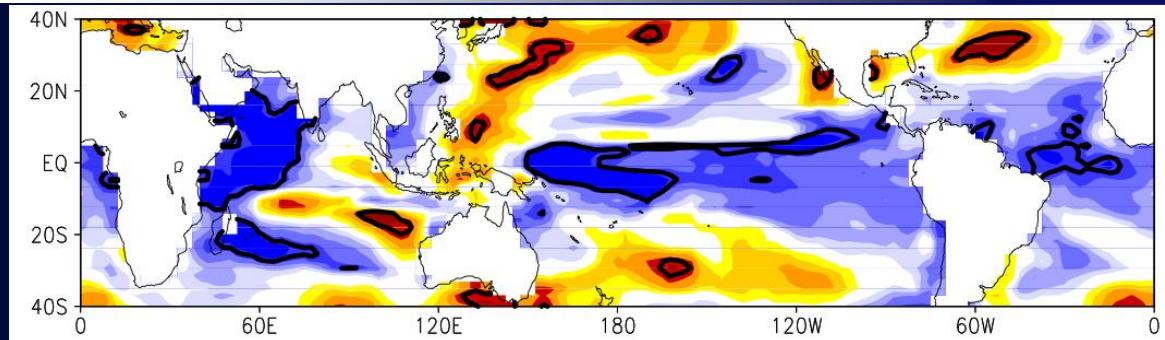
Ctl-CCSM
(0002–0023)



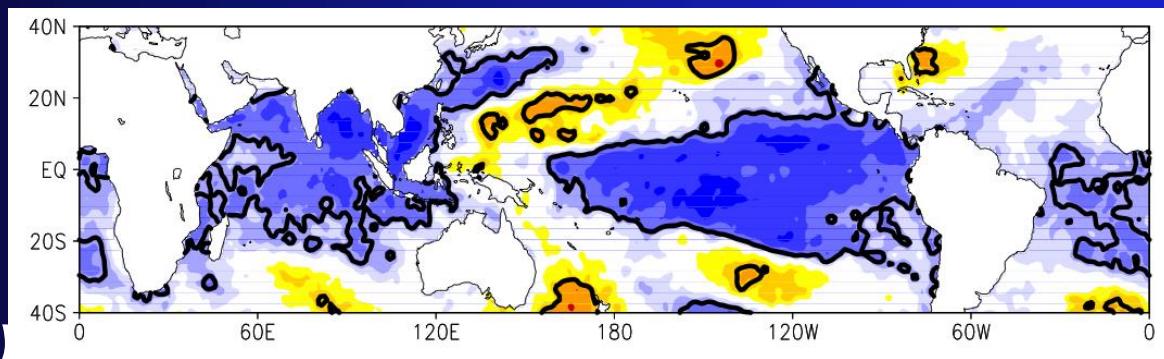
ENSO-Monsoon Relationship

IMR (JJA), SSTA(DJF+1)

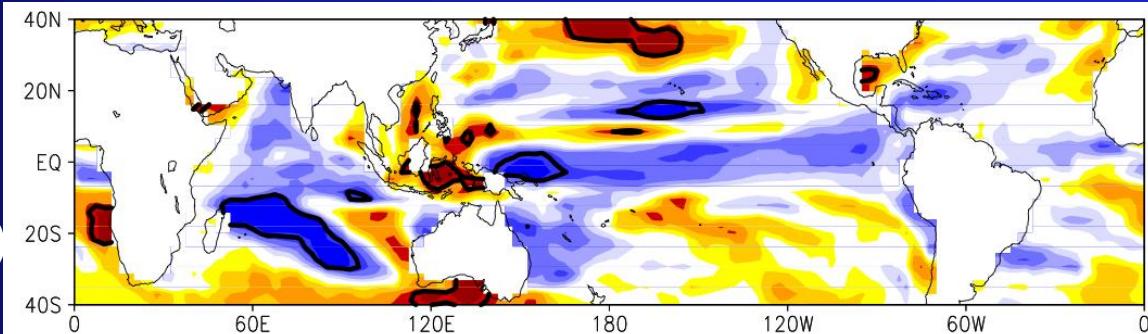
SP-CCSM
(0002–0023)



**HadISST/
GPCP**
(1951–2004)



Ctl-CCSM
(0002–0023)

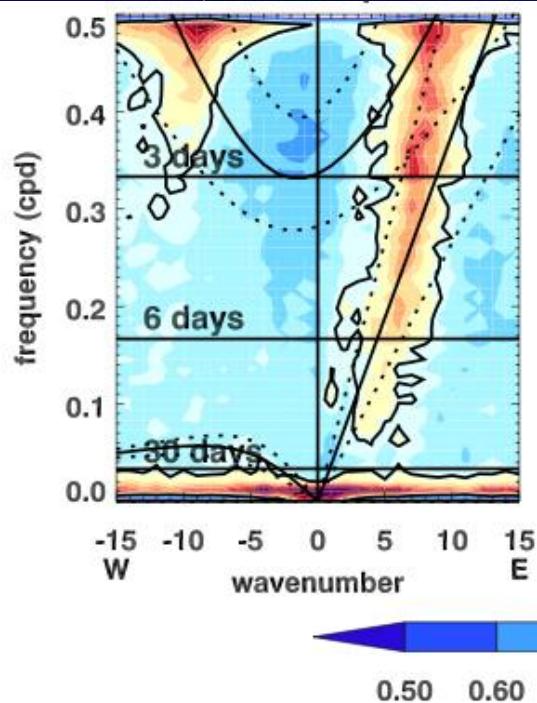


MJO Simulation

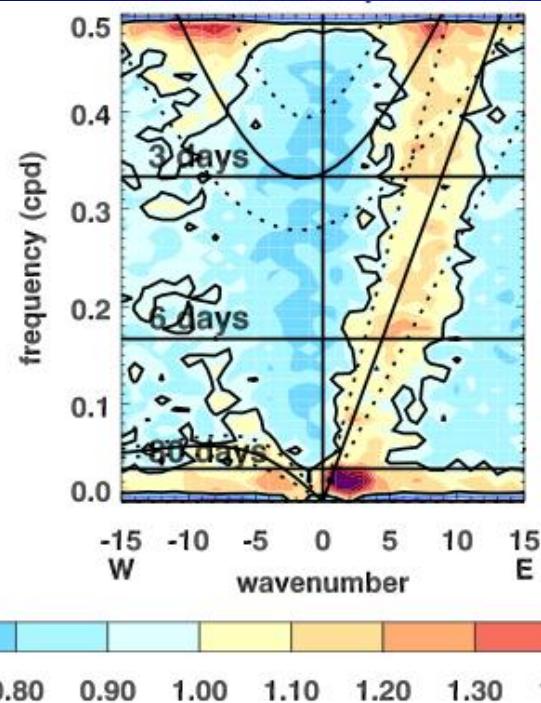
Precipitation



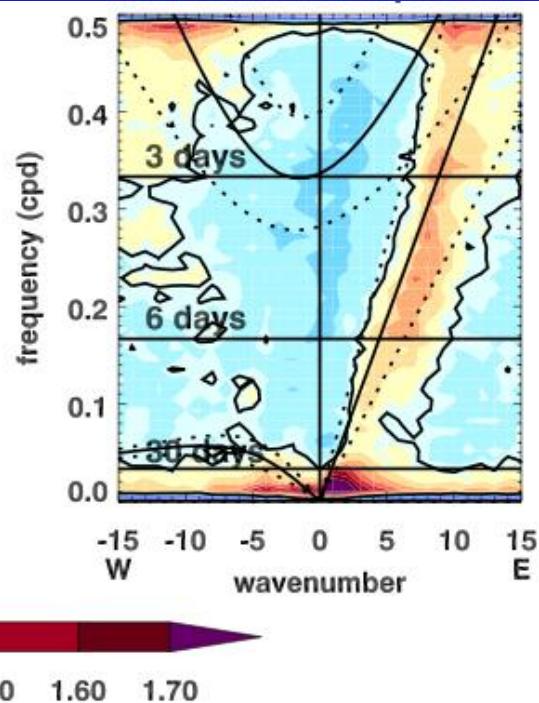
Ctl-CCSM



GPCP



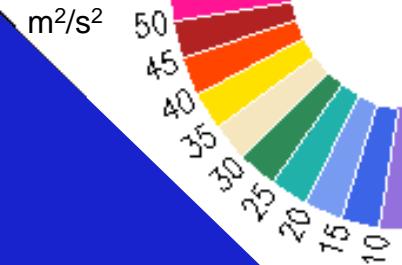
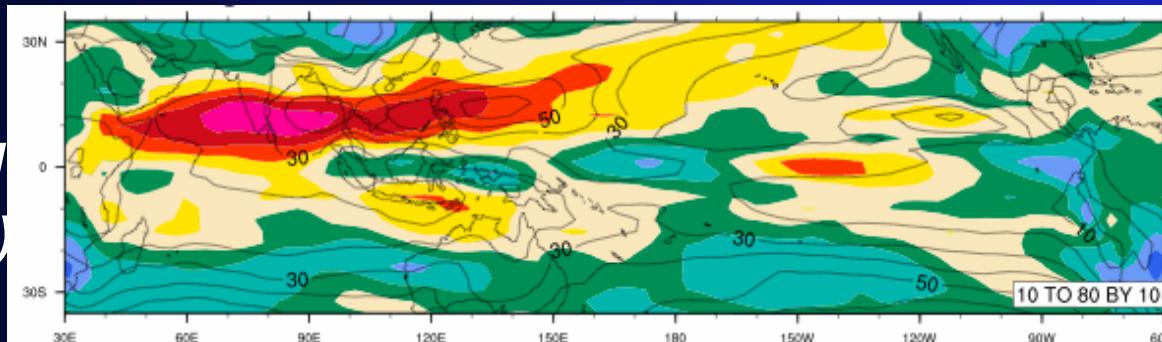
SP-CCSM



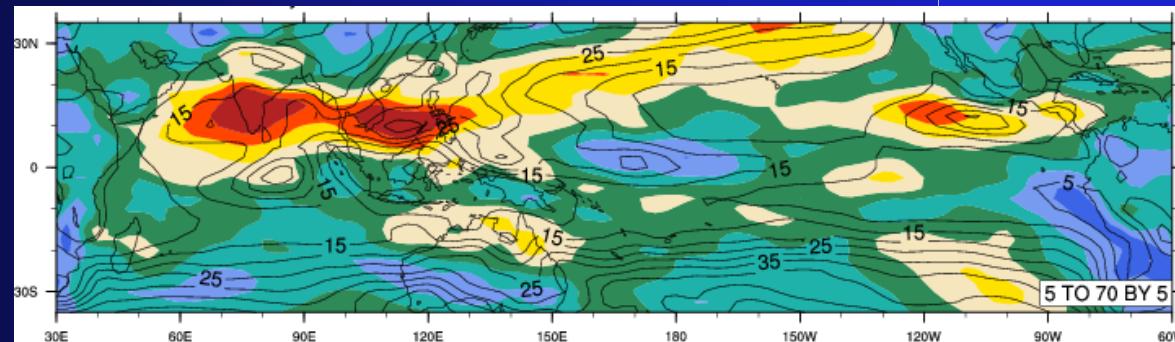
MJO Simulation

850-hPa u filtered variance, May–October

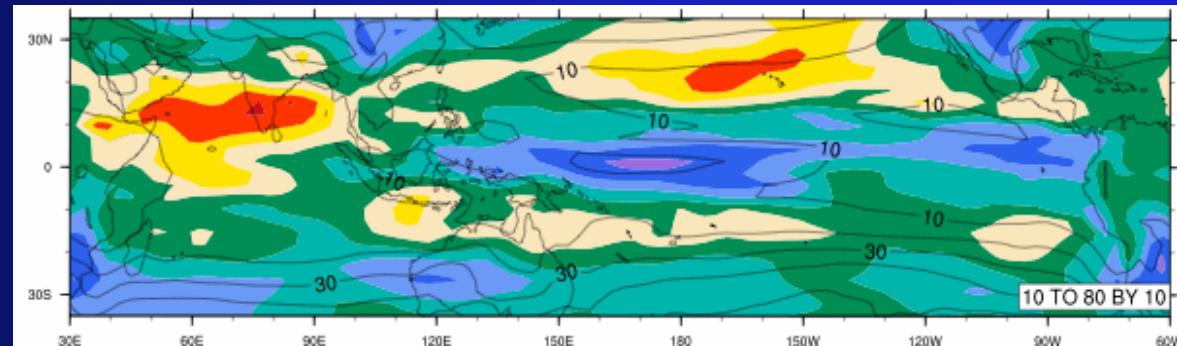
SP-CCSM
(0004–0023)



NCEP Rean.
(1990–1999)



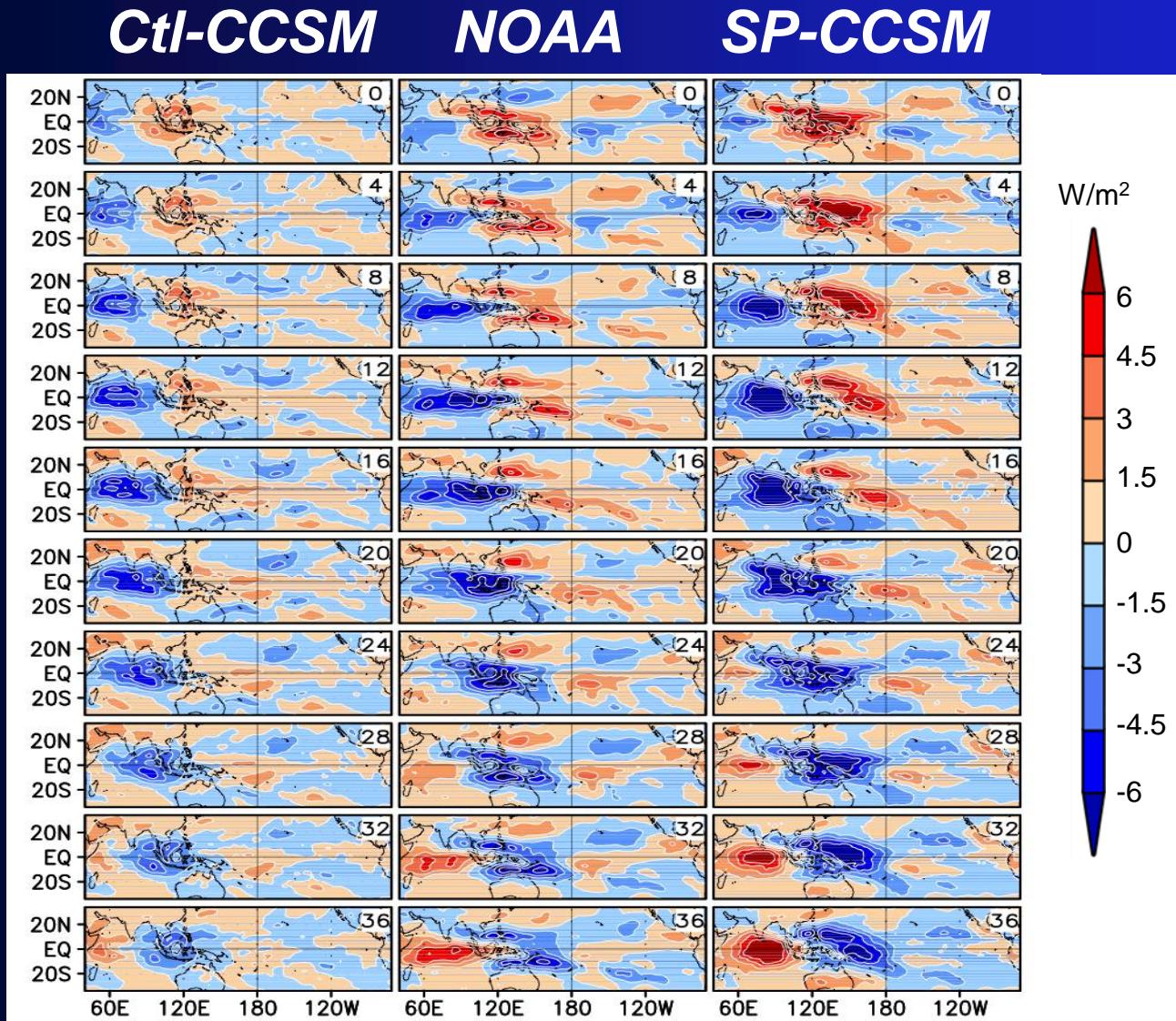
Ctl-CCSM
(0004–0023)



MJO Simulation

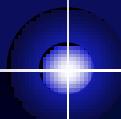
Phase composites of the OLR dominant MJO mode

(models: 0004–0023; NOAA: 1979–2007)



courtesy of
V. Krishnamurthy

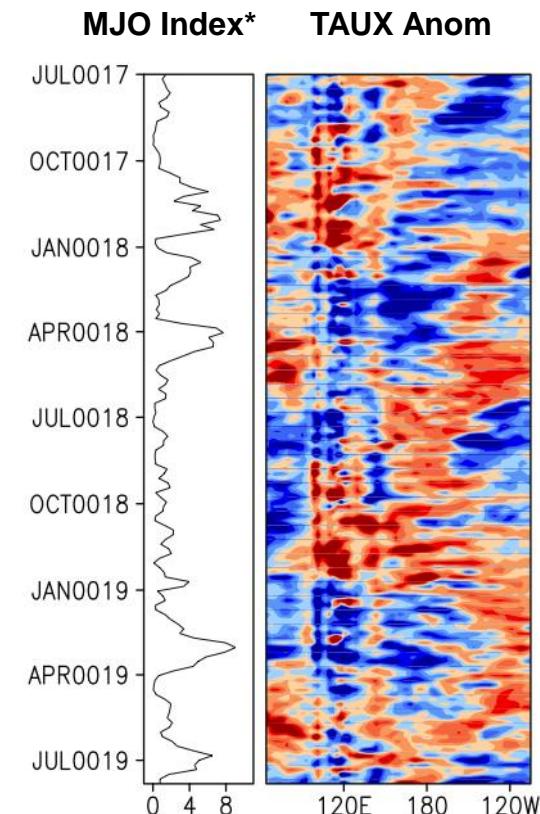
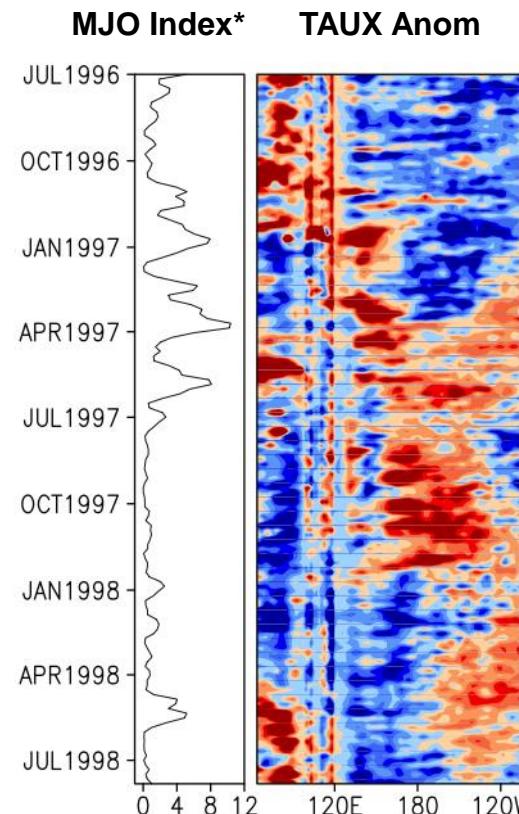
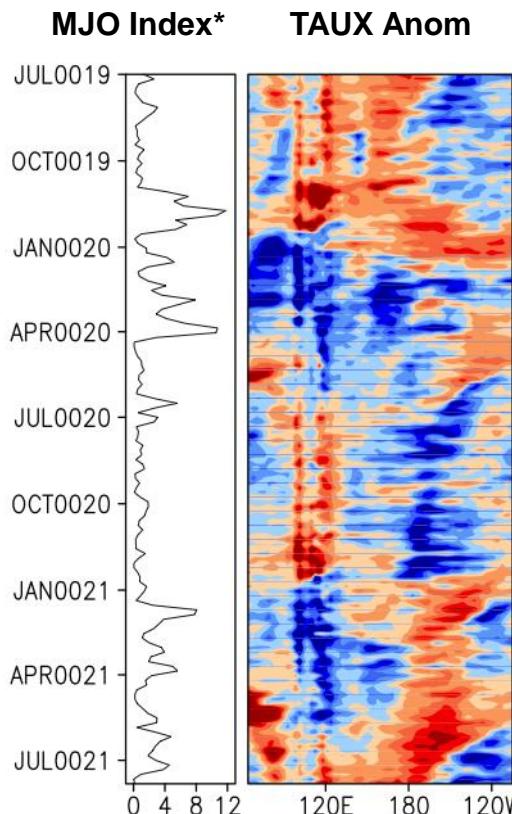
MJO-ENSO Relation



Ctl-CCSM

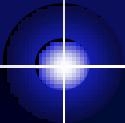
OBS

SP-CCSM



*CLIVAR definition

-0.04 -0.03 -0.02 -0.01 0.0 0.01 0.02 0.03 0.04 N/m²



Conclusions

- Replacing the cloud process parameterizations with embedded CRMs improves some of the known shortcomings of the CCSM
 - Better simulation of precipitation distribution
 - Reduced SST biases
 - Small errors in the thermocline simulation
- On interannual time-scales, the SP-CCSM produces an improved ENSO with irregular frequency of events and realistic asymmetry between the warm and cold phases
- On seasonal time-scales, the SP-CCSM simulates an improved mean monsoon with more realistic variability at the ENSO time-scale

Conclusions

- On intra-seasonal time-scales, the SP-CCSM simulates a realistic MJO
 - In the control model, the parameterization of convection results in weak convective anomalies in the Indian Ocean that cannot propagate beyond the Maritime Continent and decay before reaching the central Pacific Ocean
 - A better representation of clouds yields to alternating “active” periods of enhanced convection and “break” periods of reduced convection over the Indian Ocean are in agreement with the observations, as are their eastward and meridional propagation
- Explicitly represented convection (as opposed to parameterized convection) leads to a better simulation of the high-frequency stochasting forcing acting at the air-sea interface
 - increased MJO activity —> enhanced and more frequent westerly wind bursts —> improved ENSO
- Resolution combined with explicit representation of cloud processes are both needed!